Feed Co-Products
of the
Corn Wet Milling Process

Featuring Corn Gluten Feed & Corn Gluten Meal

Acknowledgements

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Introduction

The production of alcohol for fuel, beverage, or industrial use from corn or other cereal derived feed stocks is a major industry in North America. The primary cereal grain used in alcohol production is corn, but other cereals also are used. When feeding co-products from alcohol production, it is important to know the primary cereal grain that has been used. This publication covers only the use of corn in the production of alcohol.

Manufacturers use two major processes to produce alcohol or other starch-based products. These two processes, dry milling (mash distillation) and wet milling are very different, as are their co-products. In dry milling, or the mash distillation process, the grain is cleaned and ground dry to reduce the particle size; the entire kernel is used in fermentation. The wet milling procedure removes the maximum amount of starch from the kernel by first adding water to the grain and allowing it to steep so the starch can be removed. The starch is then converted to dextrose for further refining, and is used to convert enzymes or is fermented to produce amino acids, organic acids, gums, and other products.

The primary co-products from dry milling are distillers grains, but from wet milling they are referred to as gluten products. If several grains are used in the milling process, the greatest percentage of cereal used must be named in the co-products.

Co-products from the dry milling and/or wet milling of corn have important nutritional properties that add value to feeding rations and livestock programs. From a nutritional and financial perspective, you, the livestock enthusiast, must know these properties so you can best use them.

This publication discusses the wet milling of corn and numerous feeding advantages offered by various high quality corn co-products.

Wet Milling Feed Co-Products

Co-products from the wet milling process of corn that can be used for livestock feed are:

- **Corn Gluten Feed (CGF)** is that part of the commercial shelled corn that remains after the extraction of the larger portion of the starch, gluten, and germ by the processes employed in the wet milling manufacture of corn starch or syrup. It may contain fermented corn extractives and/or corn germ meal.

- **Corn Gluten Meal (CGM)** is the dried residue from corn after the removal of the larger part of the starch and germ, and the separation of the bran by the process employed in the wet milling manufacture of corn starch or syrup, or by enzymatic treatment of the endosperm. It may contain fermented corn extractives and/or corn germ meal.

Wet Milling of Corn

In wet milling, the corn refiner wants starch to: 1) refine and improve, 2) produce corn sweeteners, 3) ferment to make alcohol, 4) sell for its oil, or 5) produce value-added fermentation products using dextrose. In Figure 1, a kernel of corn is sliced lengthwise from top to bottom to show its primary components:

- **Starch** (lighter area in illustration). Starch is found at the top, on the sides, and in the middle of the kernel. Approximately 60% of the kernel is starch.

- **Gluten** (dark portion of illustration). Most of the protein is found in the gluten.

- **Hull and fiber** (outside of kernel).

- **Germ.** This is the seedlike pod at the bottom of the kernel where oil is found. Oil represents 4% of the kernel.

Figure 1. Components of corn.

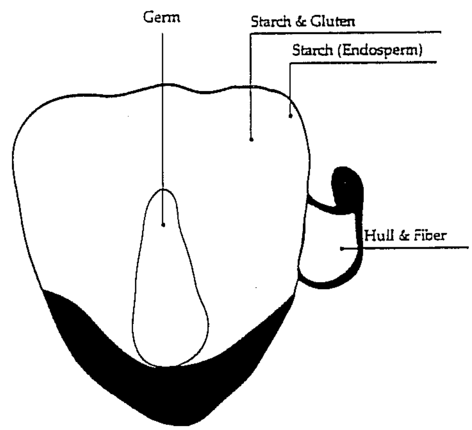
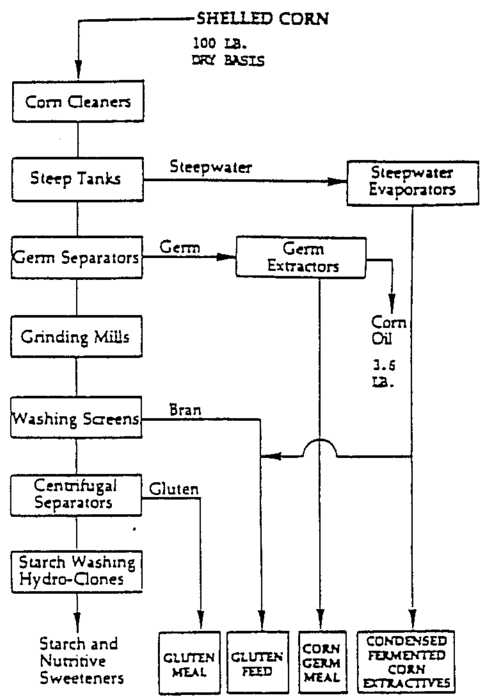


Figure 1. Components of corn.

Figure 2. Steps in the wet milling process.



The Manufacturing Process

The corn kernel is a complex mixture of starch, protein, oil, water, fiber, minerals, vitamins and pigments all wrapped in a cellophane-like package. Corn wet-milling increases the nutritional and economic value of the package by separating it into homogeneous fractions, as shown in Figure 2. Although the wet milling process was designed to produce relatively pure starch for industrial and food uses, the goal today is to find the optimum use and maximum value for each part of the corn kernel. Product quality constantly improves in response to developments in the wet milling process, refinements of nutritional requirements of animals, and consumer needs.

Production of wet milling feeds begins when shelled corn is brought to the elevator by truck, rail or barge. The corn is sampled and approved, then unloaded into bins via a cleaning system that removes all foreign material. Corn is then conveyed to large tanks, called steeps, where 1,500-6,000 bushels at a time are soaked 30-50 hours at 120-130°F in water containing 0.1%-0.2% sulfur dioxide. The sulfurous acid formed helps separate the starch and insoluble protein by disrupting the endosperm protein matrix through cleaving protein disulfide cross-links. Sulfurous acid prevents growth of undesirable micro-organisms, and allows dissolved sugars to be converted to lactic acid, which is helpful in maintaining a pH near 4.0. During the steeping process, about 6% of the dry weight is dissolved. These dissolved components provide the nutritional value for condensed fermented corn extractives (corn steep liquor), which results from partial dehydration of steepwater.

After steeping, the swollen corn kernel is about 45% water. It is coarse-milled and the germ floats to the top where it is removed, and the oil extracted by expeller or the hexane extraction process. The oil is then refined to make corn oil and the germ is dried to form corn germ meal.

After the germ is removed, an impact mill pulverizes starch particles in the endosperm while leaving fibrous material nearly intact. Bran can then be separated by screening from the starch and gluten protein. Holes in the screen allow only starch and gluten protein to pass through it, leaving the bran.

The starch-gluten slurry that remains is pumped onto a stack of whirling discs where centrifugal force causes the lighter gluten protein and water to the top, and the heavier starch to the bottom. One pass through this centrifugal separator results in a product that contains approximately 60% protein. It is concentrated, filtered, and dried to form corn gluten meal. The starch is then separated a second time to reduce protein content to less than 0.3%. A portion of the starch is dried, or modified and dried, to be sold to the food, paper, or textile industries. Corn sweeteners and ethyl alcohol are produced from the remaining starch.

Major co-products of the wet milling process are gluten, fiber, and soluble nutrients. These co-products are the basis for the industry's major feedstuffs -- corn gluten feed (CGF) and corn gluten meal (CGM). Three other products used in feed manufacturing also are produced by wet millers, but in very limited amounts. They are hydrol, a starch molasses made during the conversion of cornstarch to dextrose; wet bran, consisting of the undried hull and residual amounts of starch and protein; and dried steep liquor concentrate, manufactured by drying large quantities of corn steepwater on corn bran or corn germ.

Characteristics of Major Feed Co-Products

Dried corn gluten feed usually contains approximately 60-65% bran and 35-40% steep liquor, and also may include corn germ meal. Steep liquor usually is dried onto corn bran in a rotary drum dryer and then ground in a hammer mill. To facilitate handling, the product is pelleted, which increases bulk density to 25-37 pounds per cubic foot. Pelleting also increases availability of the amino acid tryptophan, minimizes accumulation of fines, and allows normal grain handling and storage of corn gluten feed.

Wet corn gluten feed is produced similarly to dry corn gluten feed except that the bran is pressed to approximately 35% dry matter before the steep liquor is added. The product has an oatmeal-like consistency that requires special equipment for handling wet feeds. Wet gluten feed has a pH near 4.0, allowing it to be stored indefinitely in an anaerobic environment. Other feedstuffs are usually mixed with wet gluten feed to facilitate blowing when stored in an upright silo. Depending on temperature, wet gluten feed will start to mold in 6-10 days when exposed to air.

Corn gluten meal is high in protein and energy. It consists of protein (gluten), separated in the corn wet milling process, along with small amounts of starch and fiber not recovered in the primary separation process. This high-energy concentrate is commonly provided at 60% protein. Corn gluten meal is a valuable source of methionine to complement other commonly used protein sources. The high xanthophyll content of corn gluten meal makes the product particularly valuable as an efficient pigmenting ingredient in poultry feeds. Corn gluten meal also is an excellent feed ingredient for cattle because it has a high level of rumen-protected protein.

Nutritional Values of Major Feed Co-Products

Getting the best nutrition for each type of livestock and poultry is a primary concern of the feed formulator. Each corn co-product contributes different nutritional characteristics to the finished feed in which it is used. In general, co-products from refiners are classified as "protein supplements," according to the National Research Council. All must have a minimum guaranteed protein content of at least 18%. In addition to the range of total protein content, the feedstuffs each have different levels of various essential amino acids, vitamins, and minerals.

While much of today's feed formulation is done on a "least-cost" basis, specific properties of several ingredients from corn, aside from price and availability of alternative materials, contribute to their usage.

Table 1. **Typical Nutrient Composition of Co-Products From Wet Milling Process**[1]

Nutrient	Unit	Corn Gluten Feed[4]	Corn Gluten Meal
Dry Matter	%	90.00	90.00
Protein	%	18.00	60.00
Fat	%	2.50	2.00
Fiber	%	10.00	3.00
NDF[3]	%	37.60	14.00
ADF[3]	%	12.40	5.00
Lysine	%	0.66	1.00
Methionine	%	0.30	1.27
Cystine	%	0.44	0.94
Arginine	%	0.72	1.63
Threonine	%	0.73	1.88
Valine	%	0.94	2.81
Isoleucine	%	0.67	2.5
Tryptophan	%	0.17	0.34
Linoleic Acid	%	2.20	2.00
By-Pass Protein	%	30.00	55.00
TDN[3]	%	80.00	86.00
NE-L[3]	mcal/lb	0.87	0.93
NE-G[3]	mcal/lb	0.59	0.69
NE-M[3]	mcal/lb	0.96	1.00
ME Swine	kcal/lb	1130.00	1680.00
ME Poultry	kcal/lb	830.00	1760.00
DE Horses	kcal/lb	n/a	n/a
Starch[3]	%	23.00	n/a
NSC[3]	%	27.90	n/a
Phosphorous	%	1.00	0.48
Potassium	%	1.50	0.20
Calcium	%	0.05	0.07
Magnesium	%	0.50	0.08
Sodium	%	0.15	0.06
Sulfur	%	0.30	0.65
Iron	ppm	160.00	282.00
Copper	ppm	5.00	24.00
Zinc	ppm	75.00	31.00
Manganese	ppm	21.00	7.00
Cobalt	ppm	ND	ND

[1]Data provided by Jerry C. Weigel, ExSeed Genetics

[2]Moisture Basis

[3]DM (Dry Matter) Basis

[4]Be sure DM is known, based on DCGF

Use of Wet Milling Feed Co-Products

Poultry

Corn gluten meal--Nutritional requirements of poultry vary greatly, depending on type of bird and stage of production. As nutritional requirements of broilers have become more refined, use of corn gluten meal in broiler diets has increased dramatically due to its unique nutritional qualities. Because of its high protein (60%) and energy content, it is ideally suited for the nutrient-dense high-efficiency diets sought by the broiler industry. Corn gluten meal is high in xanthophyll (approximately 225 mg/lb), the carotenoid pigment that gives egg yolks and poultry their yellow pigmentation. The energy content of corn gluten meal is second only to that of fats and oils. The high linoleic acid content also is important in helping to meet the essential fatty acid requirements of poultry. Corn gluten meal is high in methionine, an essential amino acid.

Corn gluten feed -- Corn gluten feed can be substituted for 15% of the corn and soybean meal in balanced diets of laying hens, without decreasing feed efficiency or egg production. Corn gluten feed has been fed as 10% of a grower diet and 5% of a broiler starter diet with no reduction in growth rate or feed intake.

Renewed interest in corn gluten feed has resulted from an increase in its availability and favorable pricing. There is little research data on the utilization of corn gluten feed by broilers, particularly for contemporary strains of birds. However, corn gluten feed appears to have substantial potential for use in pullet and layer rations.

An overall evaluation of the data indicates that corn gluten feed contains approximately 800 kcal of metabolizable energy per pound.

In particular, corn gluten feed may have potential use in commercial laying hen and growing pullet rations. A high dietary energy level is not as critical for obtaining optimum performance of pullets and hens as it is for broilers and turkeys. In fact, many nutritionists and breeders currently recommend lower energy feeds (1220-1260 kcal/lb) for growing pullets.

Corn gluten feed also may be an ideal ingredient for induced molting programs for layers. Results of an experiment conducted at the University of Illinois (Castanon, et al, 1990 Poultry Sci 69:1165) suggest that corn gluten feed is an excellent feedstuff for molt programs. The preliminary results show that hens fed 100% corn gluten feed or 50% corn and 50% corn gluten feed returned to egg production faster and regained body weight more quickly than did hens fed corn only. In addition, hens fed a 16% protein corn:soybean meal:corn gluten feed ration returned to egg production more rapidly and regained body weight faster than did hens fed a 16% protein corn:soybean meal:wheat bran ration.

Several studies have shown that corn co-products, such as corn gluten meal and corn gluten feed, often contain unidentified factors that produce unexplained positive responses in poultry performance. Examples of these responses include reduced liver fat accumulation in layers and improved interior egg quality. These results suggest that corn gluten feed also may contain unidentified factors that could improve performance of poultry.

Methionine and cystine levels of corn gluten meal have biological activities of 98.5% to poultry. These two amino acids are critical for poultry of all types.

Table 2.
Recommendations for Use in Poultry

Species/type	Corn gluten feed (CGF)	Corn gluten meal (CGM)
Broiler chicks	up to 2.50%	up to 5.00%
Broiler finisher	up to 5.00%	up to 10.00%
Layers	up to 2.50%	up to 10.00%
Pullets	up to 2.50%	up to 5.00%
Turkey poults	up to 2.50%	up to 5.00%
Turkey finisher	up to 5.00%	up to 10.00%
Ducks	up to 2.50%	up to 5.00%
Game birds	up to 2.50%	up to 5.00%
Breeders	up to 25.00%	up to 10.00%

Source: Jerry C. Weigel, ExSeed Genetics

Swine

Corn gluten feed (CGF) can be purchased in three ways: wet CGF, which contains about 43% dry matter; dry, loose CGF, which is wet CGF that has been dried to contain about 90% dry matter; and dry, pelleted CGF. For several reasons swine producers should use dry, pelleted CGF if possible. First, there are major handling advantages to the pelleted CGF. Second, the pelleting process improves the availability of the amino acid tryptophan (Yen, et al, 1971)[1]. Tryptophan is the first-limiting amino acid in CGF. Deficiencies of tryptophan in swine diets reduce feed intake. Because of the low level of tryptophan in CGF and tryptophan's poor availability to swine, high levels of CGF in a swine ration suppress feed intake. Thus, reduced feed intake can be alleviated, in part, by using pelleted CGF with its improved tryptophan availability.

Wet CGF can be used in gestation rations, however, wet CGF will stay fresh for only about 7-10 days. Freshness, freight charges, and handling difficulties can be major obstacles to feeding sows and gilts with wet CGF.

Edwards and co-workers (1984)[2] fed finishing pigs with diets that contained 0%, 10%, 20%, or 30% CGF and determined the effects on performance and carcass quality (see Table 3). Isocaloric diets were formulated to contain 0.89% lysine. Based on their weight, pigs were fed a maximum of 5.7 pounds per pig per day. There were no effects of treatment on gain or feed efficiency, however, increasing CGF in the diet results in leaner carcasses and darker, more yellow backfat. The level of linoleic acid in the inner backfat layer increased with increasing levels of CGF. These observations led the authors to conclude that 30% CGF was the maximum level that can be fed to produce commercially acceptable carcasses. It was not clear if the ratio of the fatty acids were altered enough to cause the fat to appear soft, or if the color changes were sufficient to reduce consumer acceptability. In addition, diets were limit fed and possible effects caused by changes in intake were not seen.

Table 3.
Effect on Performance of Finishing Swine With CGF Substituted for Corn in Diet, 61-Day Trial

	Percent CGF			
	0	10	20	30
Ave. daily gain (lb)	1.65	1.63	1.72	1.70
Feed conversion rate	2.91	2.91	2.79	2.83
Ave. carcass weight (lb.)	139.30	136.80	141.20	141.0
Dressing percent	75.70	74.60	75.00	75.10
Backfat, (in)	1.12	1.07	0.99	0.98

Source: Edwards, et al. 1984
Note: Rations contained 1,303 kcal digestible energy (DE) per lb. and 0.89% lysine.

Table 4.
Effect on Performance of Growing Swine With CGF Substituted for Corn in the Diet, 28-Day Trial

	Percent CGF			
	0	10	20	30
Ave. daily gain (lb)	1.28	1.28	1.34	1.25
Ave. daily feed intake (lb)	4.71	4.77	5.08	4.82
Feed/gain	3.68	3.73	3.79	3.86

Source: Yen, et al, 1971.
Note: Forty pigs with an average initial weight of 103 lb were fed individually. The control diet contained 12% crude protein, 0.44% lysine, and 0.10% tryptophan.

More than a decade ago, workers at the University of Illinois[3] evaluated CGF as a feed ingredient in swine diets. The performance of finishing pigs was not reduced significantly when CGF was substituted for corn, up to a dietary level of 30%, in a 12% crude protein (CP) diet of corn and SBM (see Table 4). In a 16% CP diet fed to growing pigs, a level of 30% CGF slightly reduced gain and gain-to-feed ratios, but gains were similar if the diets were pelleted. Using isonitrogenous diets with amino acids supplemented, Yen and co-workers (1971)[4] demonstrated the poor availability of tryptophan in CGF.

Current research at the University of Illinois has evaluated the effects of CGF on growth performance and carcass characteristics of finishing swine (Jones, et al, 1985)[5]. Four levels of CGF (0%, 10%, 20%, and 40%) were fed in five treatment conditions; the fifth treatment contained 40% CGF (no soybean meal) plus crystalline L-tryptophan. Diets were kept at 0.66% lysine by using crystalline L-lysine but were not kept isocaloric. Pigs were fed the experimental diets from 127 pounds until slaughter at 228 pounds. They were housed five to a pen and each treatment was replicated five times.

The growth performance of the pigs is presented in Table 5. Average daily gain and feed efficiency were significantly lower for pigs fed the 40% CGF diet without supplemental tryptophan. If the average daily feed intake on the basis of metabolizable energy is adjusted, the gain per unit of metabolizable energy intake did not differ, although the intake of metabolizable energy was different. This observation indicates pigs were able to perform on the energy they consumed, but the problem appears to be with the intake. Pigs did not consume enough to meet energy needs. One explanation may be that, even in the tryptophan-fortified diet, tryptophan still may be limiting, which would depress intake.

The carcasses of pigs fed under the five-day dietary treatments were not different in the measured depths of fat, carcass length, USDA muscle score, loin eye area, color, and firmness. There were differences in marbling, but results were inconsistent and cannot be explained. An interesting observation is that pigs fed the diet of 40% CGF without tryptophan had different characteristics for the digestive tract. These pigs had a heavier digestive tract and large intestine weights, expressed as a percentage of slaughter weight, compared to pigs fed in the following treatments: no CGF; 10%CGF; 40% CGF plus tryptophan. This difference may be caused by greater fermentation in the hind gut of pigs fed a diet that was deficient in amino acids. The differences in digestive tract, however, did not significantly influence the dressing percentage of the pigs.

Table 5. Performance of Finishing Pigs Fed Corn Gluten Feed (CGF) at Four Levels with Supplemental Amino Acids

Percent of corn gluten feed	0	10	20	30	40
Amino Acid Added	none	Lysine	Lysine	Lysine	Lysine, tryptophan
Average daily feed gain, (lb)	1.76[a]	1.66[a]	1.63[a]	1.14[b]	1.59[a]
Average daily feed intake, (lb)	6.62[a]	6.57[a]	6.36[ab]	5.65[b]	6.39[ab]
Feed/grain ratio	3.76[a]	4.00[a]	3.92[a]	4.93[b]	4.02[a]
Metabolizable energy intake per day, megacalories[1]	9.84[a]	9.51[ab]	8.94[ab]	7.52[c]	8.50[bc]
Gain/unit of metabolizable energy intake, lb per megacalorie	0.18	0.17	0.18	0.15	0.19

Source: Jones, et al, 1985

[ab] Means with a common superscript do not differ significantly (P<.05).

[1] A megacalorie = 1,000 kilocalories.

Honeyman, et al, 1990 (Journal of American Animal Science, 68:1329) fed corn gluten feed pellets for three reproductive cycles. This suggests that for gestating sows, corn gluten feed provides 70% of the energy value of corn. Based on this data, it can be concluded that most of the energy and some of the amino acids for gestating sows can be met with corn gluten feed.

Table 6. Diets and Performance of Sows Fed CGF Diets

Diets	Corn-Soy	CGF-Low	CGF-High
Corn	87.20	0.00	0.00
Corn gluten feed	0.00	92.20	93.70
Soybean meal (47% CP)	9.20	5.00	3.60
Limestone	0.95	0.95	0.95
Dical phosphate	1.60	0.80	0.70
Vitamins, TM	0.55	0.55	0.55
Salt	0.50	0.50	0.50
	100.00	100.00	100.00
Calculated analyses:			
Protein, %	12.00	20.80	20.10
Net energy, kcal/lb	995.00	816.00	719.00
Lysine, %	0.50	0.45	0.41
Tryptophan	0.10	0.08	0.07
Gestation feed/day, lb	4.00	5.00	5.70
Summary of three litters:			
Sows completing three litters	21/26	17/26	17/26
Total litters	73.00	65.00	55.00
Number born live	10.80	11.80	11.30
Number weaned	7.80	8.30	8.20
Lactation feed, lb	267.00	283.00	269.00

Source: Honeyman, et al, 1990

CG M also can be used in swine feed. It can be a protein source and an essential supply of methionine and cystine, which research shows to be limiting in grow/finishing feeds.

Remember that co-products from the wet milling process are deficient in lysine and tryptophan. Both amino acids are needed, so it is extremely important to supplement these two amino acids in the diet when gluten feed or gluten meal is used.

Table 7.
Recommendations for Use in Swine

Species/type	CGF	CGM
Starting pigs	up to 2.50%	up to 5.00%
Nursery pigs	up to 5.00%	up to 5.00%
Growing pigs (40-120 lbs)	up to 7.50%	up to 8.00%
Finishing pigs (120 lbs-mkt.)	up to10.00%	up to 8.00%
Gestating sows	up to 50.00%	up to 10.00%
Lactating sows	up to 10.00%	up to 10.00%
Breeding boars	up to 25.00%	up to 10.00%
Replacement gilts	up to 20.00%	up to 10.00%

Sources

1. J. Anim. Sci. 33:987

2. Corn Gluten Feed, The Future of Feeding, Ill. Corn Growers Assn.

3. Corn Gluten Feed, The Future of Feeding, Ill. Corn Growers Assn.

4. Corn Gluten Feed, The Future of Feeding, Ill. Corn Growers Assn.

5. Corn Gluten Feed, The Future of Feeding, Ill. Corn Growers Assn.

Aquaculture

Fish require a higher percentage of protein in their diet because fish have a lower energy requirement. The majority of fish feeds, except salmonids, contain 28-36% protein. Historically, fish meal has been the major component of the ration, but fish meal is expensive and quality often varies.

Corn co-products, such as gluten meal and gluten feed, are cost-effective and maintain constant quality.

Research reported by D.J. Sessan Y.V. Wu, USDA, ARS, Peoria, Illinois (Inform, Vol 7, No 3, March 96) demonstrates that tilapia feed containing 16% CGM or 16% CGF, balanced accordingly, performed as well as diets that contained fish meal. Flavor evaluation studies demonstrate that corn gluten feed or gluten meal with soybean meal-based diets do not affect the quality of meat from channel catfish or tilapia. Work by Weigel, ADM, also suggests that the level of CGM at 15% of the diet enhances tilapia production. Work by Wu, et al, 1995 (Progressive Fish Culturist 57:305-309) demonstrated that Nile tilapia diets containing 16% and 19% CGF (32-36% protein) produced similar weight gains and feed conversion ratios to 32% and 36% protein commercial feeds containing at least 6% fish meal.

When using corn gluten meal with warm water fish, especially catfish, do not exceed 15% in the feed. This is due to potential excessive pigment deposits. Based on the literature, corn gluten feed and corn gluten meal can be an efficient, cost-effective replacement for fish meal.

Table 8.
Recommendations for Use in Aquaculture

Species/type	CGF	CGM
Catfish	up to 16.00%	up to15.00%
Trout	up to 7.50%	up to 10.00%
Salmon	up to 7.50%	up to 7.50%
Freshwater prawns	up to 5.00%	up to 5.00%
Shrimp	up to 5.00%	up to 5.00%
Tilapia	up to 16.00%	up to16.00%

Source: Jerry C. Weigel, ExSeed Genetics

Specialty Feeds

Corn Gluten Meal (CGM) - One of the premier places that corn gluten meal can be used is in cat food. CGM has an excellent cystine content which enhances the palatability of dry, extruded cat foods. Because of the good digestibility of essential amino acids, CGM is an excellent protein source for all companion animals. CGM contains linoleic acid and the amino acid methionine, which aids in coat condition.

CGM can be used in horse feeds. Its concentration of nutrients allows it to be used as a protein and energy source in high performance horse feeds. The use level will depend on the age and desired level of productivity of the horse.

Corn Gluten Feed (CGF) - An excellent source of fiber, CGF is an effective feed ingredient for older, mature dogs. It also can be used in diets for obese dogs.

CGF can be used in complete horse feeds. The oil content in linoleic acid provides an essential fatty acid required for sheen on a horse's coat. Its fiber and low starch content does not create digestive upsets, but provides adequate energy for the mature horse. Corn, however, is high in starch and may create digestive upsets.

Table 9.
Recommendations for Use

Species/type	CGF	CGM
Puppies	up to 5%	up to 5%
Mature dogs	up to 10%	up to 7.5%
Maint. feeds	up to 15%	up to 7.5%
Dry cat food	up to 5%	up to 7.5%
Young horses	up to 7%	up to 5%
Mature horses	up to 10%	up to 7.5%
Working horses	up to 7.5%	up to 5%

Source: Jerry C. Weigel, ExSeed Genetics

Beef Cattle

Illinois researchers conducted the first extensive comparison of wet and dry corn gluten feed and wet and dry distillers grains in 1985 (Firkins, et al, 1985)[1]. In eight cattle feedlot experiments, they concluded that up to 50% of the ration dry matter of these products could be fed and still maintain cattle performance. Trenkle (1986)[2] discovered that the energy value of wet or dry corn gluten feed decreased as the level increased from 30% to 60% of the diet dry matter when replacing corn in a 78% grain feedlot ration. In a later study (Trenkle, 1987a)[3], when corn gluten feed was substituted for corn grain and corn silage on a comparable fiber basis, cattle performance was maintained. Wet corn gluten feed and dry corn gluten feed were calculated to have 98.5% and 87.4%, respectively, of the energy value of corn in this study.

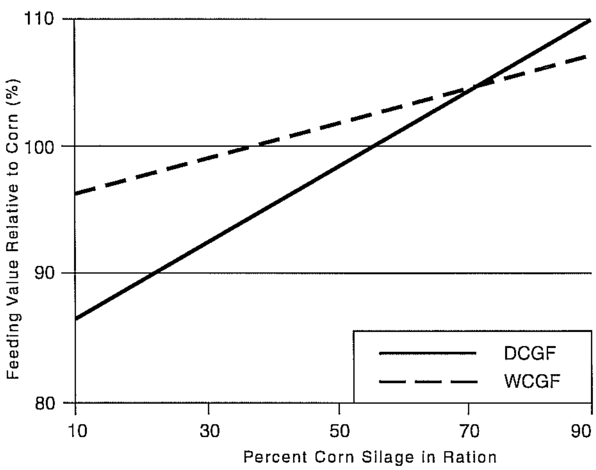
Similar results were obtained by DiCostanzo, et al (1986b)[4]. This Iowa study led to the development of no-roughage corn--corn gluten feed finishing rations for feedlot cattle (Trenkle, 1987b)[5]. Optimum levels for these types of feeding programs appear to be 45-60% of the diet with no negative effect on performance, carcass characteristics (Trenkle, 1988a)[6] or beef palatability and tenderness (Trenkle, 1988b)[7]. DiCostanzo, et al (1986a)[8], Kampman (1989)[9] and Trenkle (1988c)[10] each found corn gluten feed to substitute equally for corn grain in corn silage diets up to 50-60% of the ration dry matter.

Researchers from the North Central Region (NCR-88, 1989) summarized these and other studies and calculated the relationship between the level of corn silage in the diet on feeding value of wet and dry corn gluten feed, as shown in Figure 3.

This is based on 31 experiments involving 2,700 cattle in seven states.

The protein quality of corn gluten feed also has been evaluated by DeHann, et al, 1983[11], Trenkle, 1987d[12]; Loy, et al, 1987[13]. These studies indicate that corn gluten feed is nearly equal to soybean meal as a protein source for growing cattle. Recently, McCoy, et al (1996)[14] conducted one receiving and one finishing study to evaluate the effect of escape protein sources (feather meal/blood meal) in cattle diets with and without wet corn gluten feed. Escape protein did not improve the performance of cattle fed a 40-55% corn gluten feed ration, suggesting that this level provides adequate amounts of bypass protein for many production situations.

Figure 3.
Effect of Roughage Level on Feeding Value of Wet and Dry Corn Gluten Feed for Beef Cattle



Source: NCR-88, 1989.

Because of the high level of digestible fiber, corn gluten feed has advantages in high roughage, low energy diets over corn grain (Hannah, et al, 1990)[15]. This was demonstrated by Missouri researchers (Cordes, et al, 1988)[16] who supplemented grass hay with wet or dry corn gluten feed in four digestion trials and one growth trial. The supplements did not depress hay intake or reduce fiber digestibility, as was seen with a mixture of corn and urea. Willms, et al, (1987)[17] and Fleck, et al, (1988)[18] compared dry corn gluten feed to soybean meal-corn or soybean meal as a supplement for beef cows fed corn stalklage or native grass hay, respectively. Corn gluten feed proved to be an effective source of energy and protein for cows on low quality forage diets in both studies.

Corn gluten feed has been evaluated in other unique production situations including starter diets for Holstein bull calves (Chester-Jones, et al, 1987)[19] and restricted intake growing programs (Berger, et al, 1992[20] and Hussein, et al, 1995)[21]. Corn gluten feed appears to work well in these growing programs where intake is restricted to target a specified daily gain.

The most recent research on using corn gluten feed in beef cattle has centered on grain processing (Trenkle)[22] and the addition of supplemental fat. In two feeding trials and one digestion trial, Trenkle saw no effect or a reduction in performance and fiber digestibility when 4% fat was added to dry corn gluten feed diets. However, Richards, et al, (1996)[23] did see an improvement in efficiency when 3% tallow was added to wet corn gluten-based diets.

Several results from the Richards study are noteworthy. One is that the energy value calculated for corn gluten feed was 110-120% that of corn, considerably higher than the previous body of information. One hypothesis for this result is the reduction in the incidence of subacute acidosis, a common problem of cattle fed high-grain, high-starch rations. In fact, Krehbiel, et al, (1995)[24] found that wet corn gluten feed diets, while not eliminating subacute acidosis, reduce the time exposed to the acid insult.

Also in the Richards study, an outbreak of polioencephalamalacia (PEM) occurred on a treatment fed 100% corn gluten feed. This problem is sometimes associated with thiamine deficiency in the rumen and has long been implicated in wet corn gluten feed diets due to their high sulfur content. Testimonial evidence has been strong enough that supplemental thiamin is routinely added to wet corn gluten feed diets. This was the first time a PEM outbreak occurred under experimental conditions. The researchers injected infected animals with 4 ml of thiamin (a common treatment) and fed 50 ppm copper as copper oxide in an attempt to tie up sulfur in the rumen. No further problems occurred, but it is not known which treatment was effective.

Dairy Cattle

As profit margins continue to decrease, dairy producers have focused more attention on their feeding program because feed is the largest single expense item (ranging from 40-60%) in the cost of producing milk. Other factors, such as labor, building and equipment costs, land value, taxes, and depreciation also affect profit. Except for labor and feed, costs of producing milk are fixed and do not change from one producer to another. Consequently, development of an economical feeding program is a primary concern of most dairy producers. Development of a profitable dairy enterprise involves making nutritional as well as economical assessments of feedstuffs that are or will be used in the feeding program. Recent trends toward larger herd sizes and increased use of total mixed rations (TMR) have resulted in more dairy producers looking at various co-product feedstuffs such as corn gluten feed and corn gluten meal.

Many feeding trials with wet (WCGF) and/or dry (DCGF) corn gluten feed have been reported in the past several years. Table 10 summarizes research results reported when WCGF and DCGF were fed to lactating dairy cows. In general, both products are excellent feeds for lactating dairy cattle, resulting in similar levels of intake and production of fat-corrected milk. The data indicate that up to 25-30% (on a dry matter basis) of either WCGF or DCGF can be incorporated into the diets of lactating dairy cows without any decrease in milk yield. Consequently, the decision about whether to incorporate CGF into the diets of lactating dairy cows should be based on economics. The decision should consider the relative price of CGF compared to other available feedstuffs.

Few studies have reported growth and feed efficiency for replacement dairy heifers, although there have been numerous studies with steers. The Illinois study looked at WCGF, alfalfa haylage, and oatlage as the sole feedstuffs fed to growing replacement dairy heifers in an 83-day feeding trial (see Table 11). Average daily gains were higher for heifers fed WCGF than for heifers fed other forages. The daily weight gains for the heifers fed WCGF exceeded current National Research Council recommendations, suggesting a predisposition to fattening. Thus, WCGF should not be offered as the only feedstuff for growing replacement dairy heifers.

Corn gluten feed is low in fat and starch, but high in digestible fiber. Because most of the starch has been removed, the feed may create a higher rumen pH (less acidity), resulting in a reduction in rumen acidosis and incidences of cows going "off feed." Also, the relatively high neutral detergent fiber and lower acid detergent fiber level indicates a high percentage of hemicellulose, which is highly digestible. Thus, many of the trials with lactating dairy cows demonstrated an increased percentage of milk fat in cows fed corn gluten feed. Corn gluten feed usually contains about 18% crude protein, which is relatively soluble (>60%). For diets characteristically low in fiber and protein but high in starch, such as those based on corn and corn silage, CGF appears to be a great alternative.

Corn gluten meal also can be used in ruminant rations. CGM has a 55% by-pass value so it works well in growing rations and high producing, lactating cow feeds. CGM is an excellent source of methionine and, blended with blood meal or fish meal, becomes an excellent component of a protein blend. It can also be used in creep feeds, as well as brood cow feeds up to 30% of the ration. Corn gluten meal is a good feed ingredient added to receiving or starting cattle rations. The use level depends on the crude protein desired and other components of the feed, but it is recommended that these receiving rations contain 40% bypass protein.

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Table 10. Results of Feeding Wet (WCGF) or Dry (DCGF) Corn Gluten Feed to Lactating Dairy Cows

(MacCleod et al, 1985[1])	% WCGF	% WCGF	% WCGF	
	0.00	18.60	37.10	
First lactation				
Dry matter intake (lb)	33.90	35.40	34.80	
Milk yield (lb)	47.10	46.60	45.30	
Milk fat (%)	3.76	3.78	3.97	
Milk protein (%)	3.17	3.19	3.11	
Older cows				
Dry matter intake (lb)	44.20	41.60	40.00	
Milk yield (lb)	72.20	66.40	64.50	
Milk fat (%)	3.48	3.50	3.62	
Milk protein (%)	3.09	2.98	2.94	
(MacCleod et. al., 1985)	% WCGF	% DCGF	% WCGF	
	0.00	26.00	26.00	
Dry matter intake (lb)	38.30	42.20	36.30	
Milk yield (lb)	57.40	59.20	53.20	
Milk fat (%)	3.03	3.47	3.60	
Milk protein (%)	3.20	3.34	3.20	
4.0% fat-corrected milk (lb)	49.30	53.00	50.20	
(Staples, et al, 1984[2])	% WCGF	% WCGF	% WCGF	% WCGF
	0.00	20.00	30.00	40.00
Dry matter (%)	64.90	56.30	53.00	50.40
Neutral detergent fiber (%)	30.90	39.20	42.40	45.20
Acid detergent fiber (%)	16.90	19.00	19.90	20.70
Dry matter intake (lb)	52.80	51.30	48.80	47.30
Milk yield (lb)	67.10	65.80	61.80	61.80

Table 10. (Cont.) Results of Feeding Wet (WCGF) or Dry (DCGF) Corn Gluten Feed to Lactating Dairy Cows

(Gunderson, et al, 1988[3])	% WCGF	% WCGF	% WCGF	% WCGF
	0.00	10.00	20.00	30.00
Dry matter intake (lb)	47.20	47.20	46.30	46.30
Milk yield (%)	50.50	50.70	50.90	51.10
Milk fat (%)	3.71	3.80	3.71	3.89
Milk protein (%)	3.36	3.28	3.23	3.28
3.5% Fat Corrected Milk (lb)	52.20	53.10	52.70	54.50
(Armentano & Dentine, 1988[4])	lb WCGF	lb WCGF	lb WCGF	lb WCGF
	0.00	5.70	11.70	17.40
Milk yield (lb)	67.20	67.90	68.80	67.90
Milk fat (%)	3.64	3.62	3.77	3.79
Milk protein (%)	3.11	3.17	3.14	3.09
(Bernard, et al, 1991[5])	% CGF	% WCGF	% DCGF	
	0.00	27.10	27.10	
Dry matter intake (lb)	45.90	46.30	48.70	
Milk yield (lb)	65.70	65.50	68.10	
Milk fat (%)	3.71	3.73	3.47	
Milk protein (%)	3.25	3.24	3.23	
4.0% fat corrected milk (lb)	62.80	62.80	62.60	
(Fellner & Belyea, 1991[6])	% DCGF	% DCGF	% DCGF	
	21.20	38.50	57.10	
Dry matter intake (lb)	50.00	45.20	49.40	
Milk yield (lb)	59.30	58.90	58.90	
Milk fat (%)	3.60	3.50	3.10	
Milk protein (%)	3.20	3.30	3.30	
(Ohajuruka & Palmquist, 1989[7])	Low Fiber Concentrate	% DCGF 16.5	% DCGF 33.00	High Fiber Concentrate
Dry matter intake (lb)	42.30	44.10	46.10	41.90
Milk yield (lb)	68.30	71.00	71.90	66.10
Milk fat (%)	3.20	3.20	3.30	3.20
Milk protein (%)	3.20	3.00	2.90	3.00
4.0% Fat corrected milk (lb)	58.60	61.70	61.50	59.30

Table 10. (Cont.) Results of Feeding Wet (WCGF) or Dry (DCGF) Corn Gluten Feed to Lactating Dairy Cows

(Firkins et al, 1991[8])		Low Fiber Concentrate	%DCGF	%DCGF	High Fiber Concentrate
	% DCGF	0.00	20.00	20.00	0.00
	% Buffer	0.00	0.00	1.00	1.00
Dry matter intake (lb)		48.50	53.60	54.00	50.30
Milk yield (lb)		67.50	74.30	75.60	71.20
Milk fat (%)		3.88	3.66	3.83	3.74
Milk protein (%)		3.32	3.35	3.31	3.36
4.0% Fat corrected milk (lb)		66.10	68.10	72.80	67.00
(Bernard & McNeill, 1991	% DCGF	0.00	22.39	0.00	0.00
	% Soyhulls	0.00	0.00	22.65	0.00
	% Wheat midds	0.00	0.00	0.00	22.38
Dry matter intake (lb)		47.00	48.50	49.60	46.70
Milk yield (lb)		61.10	63.10	61.10	61.50
Milk fat (%)		3.50	3.50	3.67	3.47
Milk protein (%)		3.39	3.44	3.32	3.38
(Delost et al, 1989[9])		% DCGF	% WCGF	% DCGF	
		0.00	25.00	25.00	
Dry matter intake (lb)		47.00	48.30	51.60	
Milk yield (lb)		64.40	66.10	69.90	
Milk fat (%)		3.70	3.73	3.48	
4.0% Fat corrected milk		61.30	63.10	64.20	

Table 11.
Results of Feeding Wet Corn Gluten Feed (WCGF) to Replacement Heifers

	WCGF ad lib	Alfalfa Haylage ad lib	Oatlage ad lib
Crude protein (%)	21.90	18.2	11.4
Neutral detergent fiber (%)	37.90	50.8	62.1
Acid detergent fiber (%)	14.00	41.2	44.4
Dry matter intake (lb)	18.5	18.7	13.9
Average daily gain (lb/d)	2.42	.95	.66
Feed:gain ratio	7.4	19.3	21.0

Source: Jaster, et al, 1984.[10]

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